ALBERTA HORTICULTURAL RESEARCH CENTER
Brooks, Alberta

Alberta
AGRICULTURE

DISEASES OF POTATOES IN ALBERTA

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This is a revision of AHRC Pamphlet 81-14 of the same title.
All outdated copies should be discarded.

FOREWORD

This handbook is designed to assist market gardeners and commercial potato growers in Alberta who must diagnose and treat diseases and disorders of their potatoes. This publication is not intended to be a comprehensive treatment of all of the known disease problems on potatoes; rather, it includes information on the major diseases likely to be encountered. In difficult or questionable situations, the opinion of a professional plant pathologist should be sought. Control recommendations, particularly those involving pesticides, are subject to periodic change. Reference to pesticides in this publication is for the reader's convenience. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Additional copies of this publication can be obtained from: Library, Alberta Horticultural Research Center, Bag Service 200, Brooks, Alberta T0J 0J0

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BACTERIAL DISEASES

BACTERIAL SOFT ROT

PATHOGENS: *Erwinia carotovora* and certain other species of soil-borne and tuber-borne bacteria.

SYMPTOMS: When the tubers are infected through the breathing pores, blisters formed in the affected tissues collapse to produce sunken areas 0.3-0.6 cm in diameter. These give the tuber a pockmarked appearance. If the tubers are infected through large bruises, the external lesions are blisterlike; when they are pressed, rotten tissue squirts out. Infected areas are at first cream colored but later become grey brown and ooze a foul-smelling, slimy, stringlike mass of bacteria and decomposed cells. A dark border usually separates diseased from healthy tissues.

DISEASE CYCLE: The bacteria live in the soil and on tubers. Soil adhering to tubers at harvest is a source of infection. Bacterial soft rot usually occurs in association with other diseases such as leak and blackleg. It may follow freezing injury and may be serious in transit or storage if the temperature and humidity are not maintained properly. In wet years, bacterial soft rot may cause considerable damage. Infected tubers can spread the disease to healthy ones in storage.

CONTROL:

1. Control of other tuber diseases helps greatly to reduce soft rot incidence.

2. Avoid excessive soil moisture before harvest to reduce lenticel infection. Harvest tubers only when mature and when soil temperatures are less than 20°C.

3. Minimize mechanical damage to tubers during harvesting, handling and packing operations. Protect harvested tubers from desiccation by sun and wind.

4. Cool tubers of early harvested cultivars to 10°C or lower as soon as possible after harvest to remove field heat, then store at 2-5°C. During the first seven to ten days of storage of late-harvested cultivars, maintain temperatures

CONTROL: (cont'd)

of 12-16°C, 95% humidity and adequate ventilation to promote rapid healing of wounds. If the potatoes are to be shipped an appreciable distance by rail or by truck, this healing is very important. Following healing, store tubers at cool temperatures (2-5°C; 10°C for processing potatoes) and be careful to avoid frost injury. Provide good ventilation to prevent low oxygen concentrations and the development of moisture films on the tubers.

5. During washing and packaging, use clean water only for washing and change the water frequently or chlorinate to reduce the amount of soft rot inoculum. Use spray jets for washing tubers. Do not soak tubers in deep vats for long periods of time. Dry tubers after they are washed; do not package them in tight containers. Hot air driers hasten drying. Washed tubers may be exposed for four minutes to air heated to 66°C without damage. Cool tubers before packaging to avoid condensation.

6. Remove potato cull piles, discarded vegetables and plant refuse to avoid inoculum sources from which insects may transmit soft rot bacteria.

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BACTERIAL RING ROT OF POTATOES IN ALBERTA

Bacterial ring rot, a highly infectious disease of potatoes, was first described in Germany in 1913 and reported in North America in 1931. It has often caused serious losses in Alberta since 1937.

A control program carried out by the provincial government has done much to reduce losses from this disease. That program has the objective of eradicating ring rot bacteria on infested farms and of preventing their spread. In 1939, bacterial ring rot was named a "pest" under the Agricultural Pests Act of Alberta, which imposed an obligation on all producers and handlers to control the disease. In Alberta, potato plantings over 1 acre in size are grown under permit and the crop is inspected for bacterial ring rot. When the disease is found, special measures of disposal, clean-up, disinfestation, and use of certified seed are required.

Symptoms

Ring rot symptoms vary from variety to variety and even within varieties. Netted Gem exhibits different symptoms throughout the growing season. Early in the season leaves may show a slight yellowing or mottling and roll slightly upwards. Later, one or more stems in an infected hill may be dwarfed because of a shortened distance between the leaf nodes while other stems are normal. Leaflets on dwarfed stems appear as rosettes and tend to be twisted or to form a half swirl. Late in the season some plants wilt and die; such plants may or may not have shown early symptoms. The Norland variety expresses stunting, interveinal chlorosis, and wilting but does not show any rosetting.

In all varieties and in all stages of disease development, the lower stem of infected plants when cut and squeezed exudes a milky ooze.

Tuber symptom of ring rot is a cheesy cream-colored ooze in the vascular tissue. In storage, infected tubers may show an irregular cracking of the skin.

The Disease Cycle

Bacterial ring rot is most commonly initiated by the use of infected or infested tubers for seed. A seed potato may be infected but not show obvious symptoms of ring rot even if stored all winter. Yet if used for seed it will likely produce one or more diseased plants. If a diseased tuber is divided for seed, the bacteria in it will contaminate the cutting knife and unless the knife is disinfected immediately, may be spread to the next 30 or so tubers cut. Moreover if the seed-pieces from infected tubers are planted the planter will be smeared with bacteria and these in turn may contaminate more seed-pieces.

During the growing season the bacteria multiply in the seed-piece, the stem, the roots, the new tubers and even in the leaves of the growing plants. Cultivating machinery, direct contact between plants, and insects such as the Colorado potato beetle can spread the bacteria from diseased to healthy plants, but tuber infection does not necessarily follow such spread. Most infections in the field appear to arise from contaminated tubers used for seed rather than from bacteria being spread from plant to plant.

Badly diseased tubers often collapse when harvested and slimy masses of bacteria stick to diggers, tools, sacks, trucks, boxes, storage bins, etc. This slime dries and the bacteria can survive from one season to the next in this dried slime. Tubers that come in contact with such infested equipment are likely to be contaminated and some, if used for seed, will produce diseased plants.

During the winter, ring rot bacteria may multiply slowly in infected potatoes in storage and cause their breakdown. The bacteria so released contaminate nearby healthy potaotes.

Diseased tubers and vines left in a field may harbour ring rot bacteria over the winter and potatoes planted in that field the second year may become infected. It is important to note that, so far as is known, ring rot bacteria do not survive or multiply in field soil subjected to normal moisture and temperature fluctuations from one growing season to the next.

Control

1. Use certified seed.
2. Thoroughly clean and disinfect equipment, tools, trucks, and storages. A high-pressure hot water or steam cleaner is effective for cleaning equipment. Use disinfestants such as 5% formaldehyde, 10% bleach, or quaternary ammonium solutions (eg. Hy-X or Potato Gard) after the mud has been removed. When using quaternary ammonium solutions on non-metal surfaces treatment times of up to 30 minutes are required for complete control of ring rot bacteria.
3. If ring rot is found in a crop dispose of all potatoes and disinfest the storage area, machinery and equipment.
4. Sprout inhibit infested potatoes before March 1.
5. Practice crop rotation. Ring rot bacteria can overwinter in volunteer potatoes.
6. Dispose of all used sacks. Do not re-use any sacks for seed potatoes.

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BLACKLEG OF POTATOES IN ALBERTA

Initial symptoms of blackleg of potatoes are observed as missed hills due to pre-emergence blackleg (soft-rotting of seed-pieces). As infected plants develop, symptoms include stunting, leaf chlorosis (yellowing), leaf bronzing, leaf rolling, slimy moist black appearance of the lower stems followed by collapse of the entire plant.

Soft-rot of tubers may occur in the field or in storage. It can be caused by blackleg bacteria or by soft-rot bacteria. Blackleg does not have an offensive odor but other soft-rot bacteria which are usually associated with this disease, impart an offensive odor to the rotting tubers.

The blackleg organism overwinters in lenticels (surface breathing pores) of potatoes in storage, and on potato debris in the field. Soil-borne bacteria, weeds and insects can also be sources of blackleg bacteria, but the primary source is infected or infested seed.

Rotting can spread from one tuber to another in storage, but usually starts at the site of infested lenticels. If proper storage is maintained the number of bacteria in lenticels of healthy tubers will decline so by planting time very few tubers would be carrying the blackleg organism. Soft-rotted tubers are the main source of seed contamination. During grading, cutting, and planting operations many tubers may be contaminated by these bacteria. As a result infested seed-pieces are planted. These seed-pieces may decay quite rapidly resulting in misses or weakened plants. Blackleg bacteria from rotting seed-pieces can move up to 24 inches in the soil. Potato plants within this zone of bacteria, if damaged or under environmental stress can become infected. Plants may be damaged by cultivation, growth cracks, or diseases such as fusarium rot or bacterial ring rot. Environmental stress can be caused by low soil temperatures, excessive soil moisture, or reduced oxygen supply. However, if potato plants are vigorous and in good growing condition disease usually does not develop, although the new tubers may become contaminated. At harvest time tubers which become contaminated from rotting seed-pieces and rotting tubers go into storage, and the cycle is repeated.

Control of Blackleg

1. Use certified seed which is blackleg-free. Seed produced from stem-cuttings will generally be free of blackleg. Remove decaying tubers from seed before grading, cutting, and planting. Immediately remove culls from the storage area.
2. Seed-piece treatments are usually more effective at controlling dry rot than blackleg, but reducing dry rot will also reduce the incidence of blackleg.
3. Planting whole seed is recommended. Cut seed must be planted immediately after cutting. Seed-pieces should be covered with no more than 2 inches of soil.
4. Avoid planting in cold, wet soils because these conditions inhibit wound healing resulting in more blackleg in the field.
5. Avoid bruising during planting, cultivating, roguing, and harvesting.
6. Early roguing of diseased plants, including the seed-pieces, reduces the number of blackleg bacteria in the soil. Late roguing usually serves no purpose except to comply with certification requirements.
7. Sanitation is very important. Cleaning, preferably with steam or hot water under pressure, and disinfestation of bins, trucks, cultivators, plants, diggers and graders, greatly reduces the spread of blackleg bacteria.
8. Disinfestants such as 2% formaldehyde are effective, 10% bleach is less effective and quaternary ammonium solutions are ineffective against blackleg bacteria.
9. Store only healthy tubers. Do not store decayed, bruised, or frost-damaged tubers. Never store wet tubers.
10. Proper curing and storage conditions greatly reduce soft-rots in storage thus reducing the number of blackleg bacteria. Potatoes must be cured at 10 – 13°C with a relative humidity of 90% for 10 days. They should than be stored at 4.5 – 7°C in a relative humidity of 90% and adequate ventilation.

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COMMON SCAB

PATHOGEN: *Streptomyces scabies*

SYMPTOMS: Scab lesions are brown, roughened areas of varying size, more or less circular in form with irregular margins. The lesion begins as a minute brown speck at a breathing pore of the tuber or root. The spot may be single or there may be so many that they coalesce forming a more or less continuous scabby area.

DISEASE CYCLE: The scab organism occurs naturally in the soil where it lives indefinitely as a saprophyte. It usually invades newly formed tubers which are particularly susceptible to attack. Entry is gained through lenticels, stomata and wounds. In some cases, the bacteria may penetrate the cuticle directly.

CONTROL:

1. Plant scab-free or treated seed on land free of scab.
2. Use sulfur or ammonium sulfate (21-0-0) fertilizers over a period of years to reduce pH to below 5.2.
3. Use a crop rotation of three to five years, preferably with legumes.
4. Plowing down of green manure inhibits the activity of *Strepotmyces scabies*.
5. Avoid alkaline soil amendments such as lime, ashes and manure.
6. Treat seed tubers with metiram (Polyram) or Captan, or soak them in a solution of formaldehyde as follows:
   a) Cold treatment - Soak uncut tubers in a solution of 4.5 mL of 37% formaldehyde/L of water for two hours.
   b) Hot treatment - Soak uncut tubers in a warm (48-52°C) solution of 9.0 mL of 37% formaldehyde/L of water for three to four minutes, cover for one hour and dry before cutting and planting.

   Caution: Formaldehyde may damage seed tubers if the exposure period is longer or the concentration higher than is recommended.

CONTROL:
(cont'd)

7. Choose a moderately resistant variety such as Russet Burbank, Superior, Norgold Russet, Norchip, Chieftain, Viking or Norland.

8. Maintain a continuous, ample supply of soil moisture when tubers are developing, especially during the four- to six-week period following tuber initiation.

FUNGAL DISEASES

DRY ROT

PATHOGENS: *Fusarium* spp.

SYMPTOMS: Dry rot may show first as a clearly visible shrinking and darkening of part of the tuber, or it may progress toward the center of the tuber and serious decay may occur before external symptoms are visible. Depending on the variety, the diseased tissue may be light brown to black and dry to slightly moist or cheesy. Cavities containing white threads of the fungus form in the rotted tissue. The cavity walls are often tinted salmon pink or blue, and in the later stages of decay white threads of fungal growth may appear on the surface of the tuber.

DISEASE CYCLE: The fungi that cause dry rot are present in most soils. They infect tubers only through wounds or bruises. The amount of decay in storage depends on the following: concentration of the pathogen in the soil, amount of damage to the tubers during digging and harvesting, and susceptibility of the variety. Dry rot fungi do not attack growing plants. A hot, dry growing season favors development of dry rot fungi in the soil.

CONTROL:

1. Treat seed pieces with one of the following fungicides prior to planting: captan (Captan), metiram (Polyram), mancozeb (Manzate 200, Dithane M-45) or thiophanate-methyl (Easout).
2. Handle treated seed with noncontaminated containers and equipment.
3. If possible, harvest during cool dry weather.
4. Avoid bruising tubers when harvesting and grading.
5. Spray tubers with thiabendazole (Mertect) as they go into storage.
6. Store tubers for 7-10 days at 12 to 16 °C to favor wound healing, then lower temperature to 2-5°C (10°C for processing tubers). Maintain humidity at 90% RH with adequate air circulation.

CONTROL: (cont'd)

7. Irish Cobbler and Kennebec are resistant to certain species of the dry rot Fusaria.

EARLY BLIGHT

PATHOGEN: *Alternaria solani*

SYMPTOMS: The first indication of early blight is the appearance of spots on the older, lower leaves. Under suitable moisture conditions, spores are produced within these lesions and infection spreads to upper leaves. Early blight lesions are brown to black and are made up of concentric rings which produce a "target" effect. The spots increase in size and eventually the entire leaf may die. Potatoes may die from early blight as early as the middle of August if infection is severe. Yield and quality of tubers are reduced in such instances.

DISEASE CYCLE: The fungus overwinters in old foliage, refuse, vines and leaves. High humidity or water on the leaf surface is necessary for infection and development of the disease. Sprinkler irrigation provides such an environment. During each cycle of sprinkler irrigation, a life cycle of the fungus may be completed. Wind is the chief means of disseminating the spores from leaf to leaf, plant to plant, and field to field.

CONTROL: <u>Cultural</u>

1. Decrease the amount of inoculum.
   a) Crop rotation of two years. Avoid potatoes, tomatoes or eggplants in the rotation.
   b) Plow down or destroy all refuse.
   c) Plant disease-free seed.
2. Decrease the number of life cycles of the organism by irrigating according to soil moisture requirements of the crop, e.g., by following a program of irrigation scheduling.
3. Permit tubers to mature in the ground before digging. Avoid bruising during digging and handling.
4. Destroy all culls and volunteer plants from previous potato crops.

CONTROL: (cont'd)

Chemical

By following proper cultural control practices, the number of chemical applications will generally be decreased. If required, the following fungicides can be used:

Chemicals: Zineb (Dithane Z-78), maneb (Manzate D, Dithane M-22), mancozeb (Dithane M-45, Manzate 200), metiram (Polyram), captafol (Difolatan), anilazine (Dyrene), chlorothalonil (Bravo), tribasic copper sulphate (Tri-Cop) or copper oxychloride (C.O.C.S.). If appropriate, a sticker-spreader should be used as recommended by the manufacturer. Preharvest intervals - 1 day (all except chlorothalonil), 7 days (chlorothalonil).

Rate: All fungicides should be used at the manufacturer's rates. Complete coverage of the foliage is very important.

Time: Start chemical control when most of the lower leaflets (next to the ground) contain one or more spots.

Frequency: Treat the field after sprinkling when the soil has dried up sufficiently to allow equipment to go through. Continue application after each sprinkling until conditions for disease development no longer exist or the recommended preharvest interval for stopping the application of a specific fungicide is reached.

Equipment: The ground sprayer should develop 2000-2750 kilopascals pressure and contain a tank agitator. Both the upper and lower sides of the leaf surface should be covered. The sprayer should have a high capacity and be capable of putting out 900-1400 L/ha (350-550 L/ac). On the boom there should be a minimum of three nozzles per row - one over the center of the row and a drop nozzle between each row. There should be vine lifters around each tractor tire. Aircraft application should follow immediately after the sprinklers are turned off so that the moisture on the leaves can be used to spread the chemical over the leaf surface.

LEAK

PATHOGEN: *Pythium ultimum*

SYMPTOMS: Infected tubers of white-skinned varieties often have light to dark brown lesions on the surface. When tubers are harvested in hot weather, the lesions occur mostly at the stem end. The flesh of infected tubers is granular and very watery, and may range from cream through shades of brown to black. A dark brown to black line on the skin usually marks off the decayed area. Water may drip freely from tubers in the early stages of decay, especially if they are stored or shipped at high temperatures.

DISEASE CYCLE: The fungus is present in many soils and attacks the roots of many plants. It invades potato tubers through cuts or wounds and usually is followed by bacteria and other fungi. The fungus can overwinter in plant debris, especially in wet soils.

CONTROL:

1. Grow potatoes on well-drained soils.
2. Harvest tubers when they are mature, during cool weather in a manner so as to avoid bruising and injury to the skin.
3. Keep harvested potatoes as dry as possible and store them promptly after digging at the recommended temperature and humidity.
4. Tubers harvested in hot sunny weather are likely to develop leak and should be cooled below 10°C and marketed immediately.

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RHIZOCTONIA OF POTATOES

Rhizoctonia disease of potato is also known as Rhizoctonia canker and black scurf. The fungus that causes this disease, ***Rhizoctonia solani*** is present in most soils and can attack a number of weeds and crop plants.

Rhizoctonia damage on potato plants results in decreased yields and an increase in knobby and green-ended tubers. Infection of the crop can range from a trace to one hundred percent. During the growing of a potato or sugar beet crop the organism multiplies substantially resulting in extensive damage to potatoes if they are grown the following year on this same soil. Tuber-borne Rhizoctonia (black scurf) may be of minor importance as a source of this disease.

Symptoms

Any of the following disease symptoms may be present on infected plants as a result of infection by Rhizoctonia.

> ***Aerial tubers, pale green leaves, leaf roll, pinkish or purplish upper leaves, emergence failure, brownish stem or stolon cankers, swollen stems, multiple shoots on mature vines, black scurf on mature tubers, premature death of foliage, heavier than normal bloom, white felt-like covering on lower stems.***

Other parasitic or nonparasitic diseases of potato may also induce some of these symptoms.

Rhizoctonia infections are recognized by stem cankers (sunken lesions, reddish-brown to black in color) which appear on the stolons and the below-ground portions of the stem. Individual potato stems may be partially or completely girdled by this surface canker. Young sprouts may be infected and killed before they appear above ground. Later infections of the stolons and stems interfere with the downward movement of food-stuffs but not the upward movement of water. The plant compensates by forming tubers above the damaged areas near or above the soil surface resulting in tubers that green readily. The green tubers formed above ground in the leaf axils are known as aerial tubers.

Plants infected with Rhizoctonia usually bloom heavier than normal. Top leaves of these plants are lighter green than usual and are somewhat pinched along the mid-rib. In contrast nitrogen deficiency causes yellowing without pinching and current season leaf roll produces yellowing and rolling of the top leaves rather than pinching. Potatoes infected with Rhizoctonai often show a purpling or pink coloration of the upper leaves. During prolonged wet conditions badly diseased plants may have a white or off-white felt-like covering on the lower stem. This is the perfect or sporulating (spore-forming) stage of the fungus.

Tubers from diseased plants are usually rougher than normal, show a high level of greening and may have a brown to black scurf on the skin that does not wash off readily. This black scurf is made up of masses of resting structures (sclerotia) of the Rhizoctonia fungus.

Losses from this disease in quantity and quality of tubers can be considerable under conditions of high mositure, cool temperatures and high soil fertility in neutral to acid soils.

Control

1. Practice a 4 year crop rotation since the fungus can persist for many years in the soil. Never follow potatoes after potatoes, sugar beets, or legume crops, particularly peas or dry beans since these crops are all susceptible to Rhizoctonia.
2. Practice thorough weed control. Weeds such as red-root pigweed, mustards and lambsquarters may increase levels of Rhizoctonia in the soil.
3. Plant tubers in warm well-drained soil to encourage rapid growth and reduce disease incidence. Soil temperatures below 12.8°C (55°F) are favorable for Rhizoctonia infection on young potato plants.
4. Keep soil in the hill as loose as possible.
5. Over-irrigation can lead to wet soil conditions favorable to this fungus disease.
6. Cover seed-pieces with only 2 to 3 inches of soil and hill the potatoes after they have emerged to maximize growth and development of the plants.
7. Plant large seed-pieces or use whole seed to reduce disease incidence.
8. Nutrient imbalance favors attack of potatoes by Rhizoctonia.

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SEED-PIECE DECAY

PATHOGENS: Various species of soil- and seed-borne bacteria and fungi.

SYMPTOMS: Seed pieces may exhibit either a dry rot or soft decay, depending on the organisms involved. When decay occurs, poor stands result with subsequent reductions in yield. Seed piece decay can be aggravated by insect injury, freezing, low soil temperatures, excess soil water or fertilizer and improper use of seed treatments. If seed piece decay occurs after plant emergence, a weak plant may develop.

DISEASE CYCLE: The organisms which cause seed piece decay usually invade through wounds. The progress of decay is rapid under favorable conditions.

CONTROL:

1. Cut, treat and plant the same day, if possible. If cut seed cannot be planted the same day, then maintain it at 10-15°C with high humidity.
2. Never allow cut seed to sit in the hot sun or in a drying wind.
3. Use whole seed, if available.
4. Dust seed with captan (Captan), mancozeb (Dithane M-45, Manzate 200), metiram (Polyram) or thiophanate-methyl (Easout) prior to planting.
5. Plant in soil sufficiently warm and moist to promote good sprout growth and wound healing.

SILVER SCURF

PATHOGEN: *Helminthosporium solani*

Silver scurf is a widespread tuber disease that was once considered of little economic importance. However, the increasing demand for clean potatoes has recently made it a major problem. This is particularly true where potatoes are washed before being packaged for sale in plastic bags.

SYMPTOMS: Extensive round, silvery to dark brown spots form on the surface of the tubers. On wet tubers, the spots are noticeably silvery and easily seen. After prolonged storage under warm, moist conditions, spores may form in the diseased spots and make the tubers look sooty or smudgy. In storage, the spores may infect healthy potatoes. The affected areas become black and may develop small black lumps.

DISEASE CYCLE: The fungus lives in infected tubers in storage and in tuber debris left in the soil after harvest. The severity of the disease depends on the time at which the tubers are harvested; the later the harvest, the more severe the disease. Tubers may be infected to varying degrees, many of them showing no external signs of the disease.

CONTROL:

1. Plant disease-free seed tubers and practice crop rotation.
2. Harvest tubers as soon as they are mature and cull out noticeably infected ones during digging and grading. Store them under cool dry conditions.
3. Use whole seed, if available.
4. Dust seed with captan (Captan), mancozeb (Dithane M-45, Manzate 200), metiram (Polyram) or thiophanate-methyl (Easout) prior to planting.

WILT

PATHOGENS: *Verticillium albo-atrum* and *Fusarium* spp.

SYMPTOMS: Verticillium wilt: About flowering time, the leaves wilt from the bottom of the plant upward. The wilted foliage becomes yellow and then brown. Sometimes only one stem of a plant is affected, or a single stem may escape infection while the rest of the plant dies. If temperatures are low and the soil moisture high, a typical wilt does not usually develop, but the plants turn yellow and wither from the base. Severely affected plants are stunted and die quickly.

Fusarium wilt: In general, this wilt can be distinguished from Verticillium wilt by the extensive invasion of areas next to the vascular tissues. In wet, cold soil the underground part of the stem may rot early in the season, and the plant then wilts and dies. During hot, dry weather or late in the season the wilt may develop more slowly and there may be more extensive discoloration of the stem and new tubers. Sometimes the plant turns golden yellow, except for a few green leaves at the top. If soil moisture is excessive, especially in irrigated areas, the base of the stem is girdled by a rot similar to that caused by Rhizoctonia. The leaves roll upward, turn purple, and have a rosette appearance, and aerial tubers form. Severely affected tubers are discolored in the vascular area and develop a dry, powdery rot at the stem end. New tubers may develop extensive watery rot.

DISEASE CYCLE: Verticillium wilt: The wilt usually develops from infected seed pieces or from contaminated soil. The organism enters the plant through the roots and may penetrate most of the vascular tissue, including the tubers, as the season advances. The fungus may persist in the soil for two to seven years, depending on the strain of the fungus and the crop rotation practiced.

Fusarium wilt: Spores and mycelium overwinter in potato debris in the soil or in infected potatoes in storage. During the growing season, the fungus invades the roots and spreads through the plant into the tubers.

CONTROL:

Verticillium wilt:

1. Seed treatment with thiophanate-methyl (Easout) is effective in preventing infection from seed-borne Verticillium. Treated seed potatoes should be stored under well-ventilated conditions.

2. If the land is infested, practice a three- or four-year rotation including a cereal crop and hay, but not strawberries, raspberries, tomatoes, peppers, eggplants or Brussels sprouts.

3. Do not use tubers from a diseased crop for seed.

4. Control weeds that may serve as hosts for the fungus.

Fusarium wilt:

Treat the seed pieces with one of the fungicides recommended for the control of seed-piece decay and practice crop rotation and sanitation as recommended for Verticillium wilt.

VIRUS, MYCOPLASMA AND RELATED DISEASES

CALICO

PATHOGEN: Alfalfa Mosaic Virus

SYMPTOMS: The foliage symptoms are distinctive, but they do not appear until well into the growing season. Though the leaves are not dwarfed, they are strongly mottled with pale to bright yellow blotches. Only a few tubers form on each plant, and they may be cracked and misshapen.

DISEASE CYCLE: The source of infection is usually nearby fields of clover or alfalfa, or volunteer potato plants still growing in the field from a previous crop. The virus is carried to potato plants by aphids.

CONTROL:

1. Rogue infected plants.
2. Locate seed potato fields away from alfalfa and clover fields.
3. If potatoes must be planted in an alfalfa or clover field that was infected with alfalfa mosaic, destroy volunteer alfalfa and clover plants prior to planting and during the growing season when and where they occur.

CORKY RING SPOT

PATHOGEN: Tobacco Rattle Virus

Corky ring spot (CRS) was discovered for the first time in Canada in 1983 in the provinces of Alberta, Saskatchewan and Newfoundland. CRS or "spraing" as it is called in Europe, is transmitted to potato tubers by trichodoroid nematodes, namely Trichodorus and Paratrichodorus species. The disease is widespread in Europe where it is considered one of the most important virus diseases of potatoes, especially in seed production areas. It is also known to occur in Asia, Africa and South America. In the United States, CRS has been reported from California, Colorado, Florida, Idaho, Indiana, Michigan, Oregon and Washington.

SYMPTOMS: Stem mottle primary symptoms occur on potato foliage following feeding by large numbers of viruliferous nematodes on emerging stems. Secondary systemic symptoms, more common in Europe, include some stunted stems with others that appear normal. Leaves may be mottled, puckered, distorted, or reduced in size. Some European strains cause bright yellow, chevronlike stripes, arcs, and rings, which may be confused with Aucuba mosaic or mop-top virus infections.

Spraing symptoms on tubers vary in type and severity with the degree of nematode infestation, time of infection, strain of the virus, potato cultivar, environmental conditions, such as soil moisture and temperature, and type of infection (primary or secondary). Following nematode feeding directly on the tubers, external primary symptoms may be lacking or range from prominent concentric rings of alternating living and necrotic tissue to small necrotic flecks. Some cracking and various degrees of tuber malformation follow early season infection with some strains of TRV. Necrosis in the tuber flesh varies from prominent necrotic arcs and rings, usually but not always originating from surface lesions, to diffused necrotic flecks having no visible external involvement.

DISEASE CYCLE: Primary tuber infection follows nematodes feeding directly on tubers. Although the disease can be transmitted through seed tubers, transmission in this manner is infrequent, and the virus is ultimately self-eliminating. Nonviruliferous populations of Trichodorus nematodes rarely acquire

DISEASE CYCLE: (cont'd)

the virus from infected potato plants, and tuber disseminations of TRV from infected to virus-free fields has not been conclusively demonstrated. Opinions differ as to the importance of tuber dissemination. The virus can be seed-transmitted in other hosts. Movement of soil infested with viruliferous nematodes is probably the most effective means of dissemination. TRV can infect more than 400 monocotyledonous and dicotyledonous species in over 50 families. Often, it does not become systemic, remaining in roots of plants that show no foliage symptoms.

Incidence of CRS is highest in sandy soils. Twelve species of trichodoroid nematodes transmit TRV; however, not all of these feed on potatoes. Trichodorus spp. generally occur in sandy, open-textured soils and have been found at depths of over one meter. Populations of Trichodorus have remained infective in moist soil maintained in the laboratory for as long as five years in the absence of a host. The virus is not retained through the egg or in the molt.

CONTROL:

Control of CRS in areas where it is endemic has proven to be a difficult proposition. Cultivars resistant to CRS in one field may not be resistant in other fields, even in the same country. Soil fumigants such as dichloropropane-dichloropropene (D-D), 1, 3-dichloropropene + related C_3 hydrocarbons (Telone), and dazomet (Basamid), and nonvolatile organophosphate and carbamate chemicals such as phorate (Thimet), phenamiphos (Nemacur), oxamyl (Vydate), aldicarb (Temik), and carbofuran (Furadan) provide reasonably effective nematode control. However, effectiveness of chemicals has varied with location. Soil fumigation and consecutive plantings of potatoes may almost eliminate the vector from the soil because potato is a poor host for Trichodorus spp. Rotational or cover crops have been considered of little use because of the wide host range of the vector and virus. Incidence of CRS may be reduced in potatoes following cover crops such as barley, which is resistant to TRV but a good host for the vector.

Since CRS has only been found in home gardens in Alberta to date, the most practical control measures would seem to be:

1. Plant only seed potatoes free of CRS. Do not use seed from friends, relatives or neighbours if its disease status is questionable.

SYPMTOMS: (cont'd)

2. Avoid transferring nematode-infested soil from CRS-infested to non-infested gardens by ensuring that all tools, equipment and footwear are thoroughly cleaned and disinfected.

3. ANY suspect cases of CRS should immediately be brought to the attention of the local District Agriculturist, Agricultural Fieldman or nearest plant disease diagnostic laboratory, e.g., the Regional Crop Laboratories in Brooks, Olds or Fairview, and the Alberta Environmental Centre in Vegreville.

agri-fax Alberta AGRICULTURE

Agdex 258/635-7

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POTATO LEAF ROLL

Potato leaf roll is a virus disease spread by aphids, primarily green peach aphids. It is not spread by plant or tuber contact or through the soil. Green peach aphids do not have an overwintering host in Alberta nor do they mass migrate into Alberta from southern areas during summer months.

This disease, though not usually a problem in Alberta, can occur under certain conditions. Occasionally, in the spring a few green peach aphids escape from greenhouses with bedding plants. These may build up outdoors on garden plants including potatoes and could cause problems for the seed grower by introducing leaf roll virus into seed fields. In commercial potatoes in Alberta a low level of leaf roll does not pose a serious problem. However, if large numbers of green peach aphids are present in the potato fields, as in potato growing areas in the United States, the leaf roll virus is quickly spread throughout the potato crop. Tubers produced will often develop a net necrosis in the vascular tissue and are consequently undesirable for table or processing purposes. Therefore, seed potato tubers with a trace percentage of leaf roll infection should not be grown.

When the green peach aphids move from bedding plants to commercial potato fields they prefer to deposit their young on potato leaf roll virus-infected plants, usually in early August. As the aphids feed on these diseased plants they pick up the virus and once infective, they can transmit it until they die off in the fall.

When potato vines mature or are top-killed the winged aphids that develop may migrate to other food sources carrying the potato leaf roll virus. If at this time these infectious green peach aphids move to healthy potato plants or partially top-killed plants which have some regrowth, they will transmit the virus.

Potato aphids, which overwinter outdoors in Alberta, can spread potato leaf roll virus but they are not believed to be important because they are inefficient vectors of the virus . Buckthorn and foxglove aphids, which occur elsewhere in North America, and are capable of spreading potato leaf roll virus, have not been found in this province.

Leaf roll symptoms depend on the stage of infection. Seed tubers from an infected plant produce potato plants that are stunted, have a pale green color, stiff uprolled leaves, and sometimes purple top symptoms. These plants are important sources of virus for spread by aphids to healthy plants during the growing season. "Current season" leaf roll is not always easily recognized. Plants infected early in the season may have a slight rolling of the new leaves at the shoot tips. Later a yellowish or reddish color may develop near the base of the rolled leaflets and rolling and discoloration may continue downward as the vines mature. Plants infected late in the growing season may show no symptoms prior to harvesting.

Tubers from plants of some varieties infected during the current season develop a discoloration of the tissue in storage called "net necrosis". This appears as brown strands arranged in a double ring about a centimetre beneath the skin and usually is most distinctive in the stem-end half of the tuber. The amount of net necrosis will depend on the potato variety, time of infection, length of storage, and the temperature of storage. Potato varieties differ considerably in their susceptibility to leaf roll and net necrosis. All potato varieties grown in Alberta are susceptible to leaf roll and Netted Gem, in particular, to net necrosis. Kennebec, Red Pontiac, Norland, Norchip and Warba are susceptible to leaf roll but do not develop net necrosis.

Potato leaf roll can be controlled in seed fields by:

1. Early planting and early top-killing of high classes of seed.
2. Roguing diseased plants – if they occur.
3. Use of systemic insecticides (Temik or Di-systor) at planting.
4. Use of field sprays beginning in early August or if green peach aphids are present and continuing until top killing. One of the following chemicals should be used:

	ai/acre	preharvest interval
Monitor	12–15 oz	14-day
Thiodan	12–20 oz	5-day
Furadan	7– 7 oz	7-day
Dimethoate	4–10 oz	7-day
Malathion	10–15 oz	3-day
Pirimor	3– 4 oz	7-day

Copies of this and related publications may be obtained from the Publications Office, Alberta Agriculture, 9718 - 107 Street, Edmonton T5K 2C8 or District Extension Offices.

5. Early top-killing:
   Elite I by August 20
   Elite II by August 25
   Elite III by August 30
   Foundation and Certified by September 15.
6. Keep seed potato fields away from commercial potato fields and garden plots or urban areas.

Control of leaf roll in commercial fields:

1. Control volunteers if they occur.
2. Control aphids if they are present; this prevents current season spread of leaf roll.
3. Use certified seed.

Other diseases can cause a rolling of potato leaves and may be confused with leaf roll. One of these is a mycoplasma disease known as "purple-top wilt" or "aster yellows". This disease can cause leaf rolling but other symptoms, such as swollen nodes, zig-zag internodes, and aerial tubers are usually present.

Rhizoctonia, a fungus disease, can also be confused with potato leaf roll (See Alberta Agricuture Factsheet Agdex 258/635-6, *Rhizoctonia of Potatoes).*

MOSAIC

PATHOGENS: Potato Viruses A, X, S and Y

SYMPTOMS: The mosaic diseases are a group of three forms called simple, mild and rugose mosaics. These blend into one another and each form is caused by a different virus or combination of viruses. The mosaic or mottle is most prominent in cool, dull weather, such as may occur during the early part of the growing season. Though most of the mosaic viruses have distinctive symptoms, some strains have symptoms resembling those of other viruses in the group.

Simple Mosaic: This is the most common of all potato virus diseases and is found in almost every crop of susceptible varieties grown for table stock. The plants are mottled in shades of light and dark green, varying from very conspicuous to barely noticeable. The mottle is most obvious in cool dull weather. Leaves and plants are not reduced in size, and leaves are not wrinkled. The tubers have no obvious defect, although yield may be reduced.

Mild Mosaic: This disease is found in most potato-growing areas, but because it is more obvious than simple mosaic it can be kept under control more easily by roguing. Leaves of plants with mild mosaic have a light green to yellowish mottle. The leaves are slightly wrinkled or smaller than normal, and the plants are slightly dwarfed. Usually, the tubers have no obvious defects, although yields may be reduced.

Rugose Mosaic: Rugose mosaic is the most serious of the mosaic diseases and the symptoms are easily distinguished from those of simple and mild mosaics. Symptoms may vary in severity. In the first year that a plant is infected, the symptoms may differ from those in the following years. Black streaks develop in the veins, leaf stalks and stems, causing the leaves to shrivel and remain hanging from the plant by a thread of dead tissue. Later, the plant is reduced to bare stems with a few leaves at the top, giving a "palm tree" effect. If, however, infection occurs late in the season, there may be little or no development of symptoms. Tubers from infected plants produce plants with symptoms that caused the disease to be named rugose mosaic. Usually, the fully developed leaves are mottled,

SYMPTOMS: (cont'd) wrinkled, distorted and reduced in size and the leaf stalks are brittle. The whole plant is usually dwarfed and is called rugose because of its rough appearance. Tubers from infected and from healthy plants are clearly different when observed in bulk. Affected tubers are much smaller, but they have no other symptoms of the disease.

DISEASE CYCLE:

Simple Mosaic: The disease can be caused by either Potato Virus X or S. These viruses are spread to healthy plants mainly by brushing or rubbing of foliage. They can also be spread by the hands or damp clothing of roguers, by implements and by animals or insects that have been in an infected crop. Spread can also occur by contact between roots of infected plants, between seed pieces of their sprouts, and by cutting knives.

Mild Mosaic: This disease is usually caused by two viruses in combination. When a plant infected with Virus S or X becomes infected by the other of these viruses, mild mosaic often develops.

Rugose Mosaic: Rugose mosaic is caused by Potato Virus Y, alone or in combination with Virus X. However, there are many strains of Virus Y and symptoms vary in severity according to the strain. PVY is spread from plant to plant by aphids.

CONTROL:

1. Plant virus-free certified seed.
2. Control insects, especially aphids.
3. Rogue out plants with obvious mosaic, including the seed pieces, as soon as they are detected.
4. Avoid rubbing potato foliage with clothing, machinery, etc.
5. Disinfect cutting knives and equipment as often as possible. Use household bleach, soapy water or quaternary ammonia.

PURPLE-TOP WILT (ASTER YELLOWS)

PATHOGEN: Aster Yellows Mycoplasma

SYMPTOMS: Affected plants are usually stunted or dwarfed and chlorotic, producing short to tall upright secondary shoots. Leaves on such plants frequently are abnormal in shape and size. Flowers may be greenish, dwarfed, aborted or absent. The root systems of diseased plants may appear normal but are usually smaller. Tubers are often soft and spongy.

DISEASE CYCLE: The causal organism is perpetuated in infected perennial crops and weeds, various annual plants growing in the greenhouse and in bulbs, corms, tubers and other propagative units. Perennial weeds that retain the organism from one season to another include thistle, plantain, wild chicory, wild lettuce, daisies and many others. The chief vector is the aster leafhopper. Infected insects migrate northwards in spring and early summer, feeding along the way and infecting new hosts. Young leafhoppers sucking juices from the newly infected hosts pick up the pathogen. After a short incubation period, these insects are capable of transmitting the mycoplasma to neighboring plants.

CONTROL:

1. Where possible, eradicate all susceptible perennial and biennial weeds along roadways, ditch banks, fences, around greenhouses and in pastures.

2. Do not plant susceptible crops adjacent to yellows-infected crops.

3. Frequent applications of insecticides, if necessary, should control leafhopper vectors during heavy migratory periods. Susceptible weeds growing near flowers and vegetables crops should also be sprayed early and repeatedly to reduce the number of migrating leafhoppers.

4. Crops planted late where summer temperatures are near 32°C or above often escape aster yellows. This is probably due to high temperatures destroying the pathogen in virulifercous leafhoppers.

5. Rogue infected plants, if practical.

SPINDLE TUBER

PATHOGEN: Spindle Tuber Viroid

SYMPTOMS: Potato vines showing distinct symptoms of spindle tuber are upright, dwarfed and much thinner than normal vines. The stems are often more branched than usual, with the upper angles of the branches and stems abnormally acute. Affected tubers are dwarfed and are usually narrower and more spindle-shaped than normal ones. The eyes are usually abnormally numerous and the tubers are often cracked. Often, plants can be affected by this disease without showing obvious symptoms.

DISEASE CYCLE: The viroid is readily transmitted from diseased to healthy plants by mechanical means and many insects including aphids, grasshoppers, Colorado potato beetles and flea beetles. Current season transmission may occur too late to cause tubers to show symptoms, but tubers produced on vines infected late in the season will produce diseased plants when used for seed. Spindle tuber is also spread at seed cutting time by knives and planters.

CONTROL:

1. Use disease-free stock for seed.
2. Follow a good insect control program.
3. Rogue out diseased plants. Make sure the entire plant is removed.
4. Avoid mechanical transmission by planting whole, rather than cut seed, and avoid leaf contact by people and equipment in field operations.
5. Decontaminate knives and other equipment as frequently as possible using detergents, household bleach or quaternary ammonia.

WITCHES' BROOM

PATHOGEN: Witches' Broom Mycoplasma

SYMPTOMS: When healthy plants become infected, they are dwarfed, the leaves are lighter green than normal and often the leaf margins are reddish-yellow. The buds at the junctions of the main stem and the branches grow and make the plant bushy. Plants from infected seed have many shoots. These produce side shoots, making the plant look even more bushy and erect. The stems and petioles are round and smooth. The stolons are abnormally white and long and bear numerous small tubers, often in chains. As the above-ground symptoms develop, the newly formed tubers sprout and produce slender plants.

DISEASE CYCLE: The disease is tuber perpetuated. In Western Canada, two species of leafhoppers have been observed to transmit the disease from clover to alfalfa to potato.

CONTROL:

1. Plant disease-free seed. Eliminate from planting stocks all tubers that have premature sprouts, especially hair-like ones.
2. Rogue infected plants.
3. Control leafhoppers, if practical.

NON-INFECTIOUS DISORDERS

agri fax Alberta AGRICULTURE

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NON-PARASITIC DISORDERS OF POTATOES

Non-parasitic disorders of potatoes result from non-infectious agents such as mineral deficiencies, mechanical injury, cold damage or herbicide injury. Such disorders invariably result in a reduction of marketable yield and quality.

MINERAL DEFICIENCIES

Potatoes require macronutrients and micronutrients (minerals) from the soil or growing medium, which are necessary for normal plant growth. The following table lists the 13 essential nutrients which potato plants may obtain from the soil.

PLANT NUTRIENTS

Chemical Name	Chemical Symbol	Supply in Alberta soils
MACRONUTRIENTS		
Nitrogen	N	– often deficient
Phosphorus	P	– often deficient
Potassium	K	– sometimes deficient
Sulphur	S	– sometimes deficient
Calcium	Ca	– seldom deficient
Magnesium	Mg	– seldom deficient
MICRONUTRIENTS		
Boron	B	
Chloride	Cl	
Copper	Cu	
Iron	Fe	– very seldom deficient
Manganese	Mn	
Molybdenum	Mo	
Zinc	Zn	

It is important that all 13 essential nutrients are in the soil for plant use, and that they are present in sufficient and balanced amounts. If one or more of the essential nutrients is in short supply then the level of crop yield can be limited by this deficiency which becomes a production barrier. Symptoms of nutrient deficiency may show up in the potato crop as stunting, leaf yellowing (chlorosis) or leaf browning depending on the nutrient or nutrients that are in short supply. Soil testing is the best way to identify the cause of a particular problem because the soil test results give a complete account of soil nutrient levels and other soil characteristics such as akalinity or acidity that can affect plant nutrient uptake. Tissue testing to supplement soil testing information is sometimes used in pinpointing the cause of a particular problem.

MECHANICAL INJURY

If potatoes are roughly treated during harvesting, storage, and handling, the tubers may suffer varying degrees of damage, from blackspot bruise through surface skinning to shatter bruise, deep cuts, and gouges. **Blackspot bruise** is a relatively uniform discoloration of the damaged area when potatoes are peeled. A blackspot bruise usually does not penetrate deeper than 5 mm and usually does not rupture the potato skin. **Shatter bruise** appears as a fissure or a series of fissures with a discoloration at the fissure edge. Unlike blackspot, shatter bruise fissure may penetrate very deeply into the tuber. These injuries result in tubers that are much more susceptible to storage rot.

Several other factors also contribute to the mechanical injury of potatoes, including immaturity, improper soil moisture, tuber hydration (crispness) and temperature.

Immature potatoes are more prone to bruising and skinning than mature tubers with good skin set. High soil moisture may cause excessive damage because the harvester utilized more "shakers" or eccentrics to remove the tubers. Conversely, in fields that lack good soil moisture, the soil is so dry that it will not carry into the harvester far enough to cushion the tubers and prevent damage. In extremely dry fields, clods may also be a problem. When clods are moist they break up readily, but when too dry the clods will carry over into the truck and cause damage to the tubers. The relationship between tuber condition and the likelihood of damage is not completely understood. Cultural practices which have been shown to influence tuber condition

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include fertility level, irrigation practices, and vine killing. Others undoubtedly are important but have not been studied in depth. Fertility level, irrigation practices and vine killing appear to influence tuber hydration which is known to be an important factor. Crisp potatoes are highly susceptible to shatter bruise but are quite resistant to blackspot. On the other hand, limp potatoes are resistant to shatter bruise and highly susceptible to blackspot.

The temperature of the tubers at harvest also influences the total amount of damage. As a general rule, damage increases as temperature decreases.

Control – The problem of mechanical injury to potatoes has many facets. There is no one ready answer or solution. Damage is related to a combination of factors: tuber maturity, tuber hydration, tuber temperature, soil conditions, machine design and operation, and general handling. Conditions may vary from field to field, and from area to area. Therefore, it is imperative that each grower learn about his own conditions and decide how best to cope with them. General guidelines for reducing tuber injury are:

- Strive for a uniform growth pattern by the proper implementation of fertilization, irrigation and pest control practices.
- Condition soil to facilitate harvest through moisture control and avoiding compaction.
- Harvest early to avoid harvesting at low temperatures. Use daily fluctuations of temperature to advantage. Tubers harvested during the warmer part of the day show less damage.
- Use the correct chain/forward speed ratios for harvesters as calculated for soil type and predicted tuber yield. Harvester chains should be full of potatoes at all times.
- Control conveyer height to ensure that potatoes do not drop more than 15 cm.
- Use care in loading potatoes into storage. Avoid dropping potatoes great heights. Avoid roll-back on chains and roll-down on piles.

HEAT INJURIES

Potatoes that are exposed to the sun during very hot weather may be sunscalded; the affected tissue is killed, turns watery and becomes brown. A similar effect may appear on potatoes close to the soil surface if temperatures are above normal and moisture levels below normal. This exposure is usually followed by rotting of the tubers.

Control – Attention to proper hilling will reduce sunburn to a minimum. During harvest operations, reduce exposure of tubers to the wind and sun to a minimum. This may be achieved by windrowing only immediately ahead of harvesting and by not leaving potatoes in the truck in the open for any longer than is necessary.

Greening

Potatoes exposed to natural or artificial light soon turn green. Varieties differ in their sensitivity to light; Kennebec greens more rapidly than Netted Gem. The green color is due to formation of the pigment chlorophyll and may be accompanied by an increase in solanine, a glycoalkaloid which imparts a bitter taste to the tubers. Tubers having high levels of solanine are toxic if consumed.

Control – Keep tubers covered with soil before harvest. Do not leave exposed in the field. Store tubers in a dark place. Avoid long exposure to natural or artificial light in the warehouse, store or home.

MALFORMED TUBERS

Knobbiness

Knobs or protuberances, often called "second growth" develop on the main tuber at points where eyes are located. These knobs vary considerably in size and shape. Any factor that decreases tuber set or increases top growth increases knobbiness. Uneven growth caused by moisture alone is definitely not the only or primary cause of knobby growth. Moisture, however, is one of the causes. Mechanical girdling or girdling by the fungus Rhizoctonia which affects water and food material translocation, increases knobbiness.

Varieties vary in the degree of knobbiness exhibited. Knobbing is frequently observed on Netted Gem but seldom on Norgold Russet, Norland and Viking.

Control – Plant seed pieces of at least 55 – 70 g to ensure a reasonable number of stems per hill. Keep planters in good operating condition and operate carefully so as to avoid gaps during planting. *Rhizoctonia* control is essential and excessive nitrogen fertilizer use should be avoided. Soil moisture levels above 70% water holding capacity should be maintained. Maintaining this moisture level through frequent light applications of water from a pivot or wheel move system instead of flooding is recommended.

Bottlenecks, Dumbbells and Pointed Ends

Water uptake and translocation are the most important factors governing this type of uneven growth. Pointed stem-end tubers are generally the result of moisture stress early in the development of the tuber. Pointed bud-ends are the result of moisture stress later in the development of the tuber. Whenever the progress of active growth is stopped and then resumed a new tuber develops as an extension of the old tuber forming a knob or pointed end.

Control – Ensure that moisture stress conditions are not allowed to develop during the growing season.

Secondary Tubers

Several small tubers may form on plants like beads on a string, or they may form in clusters at the end of short sprouts. Growth stops and no leafy shoots develop. The disorder is evidently due to an abnormally high concentration of cell sap in the seed pieces. This condition may be induced by high storage temperatures, removal of sprouts, or planting in cold, dry soils.

Control – Avoid high storage temperatures and planting in cold, dry soil.

Growth Cracks

There may be one or more cracks in a tuber. The disorder is usually common when many of the tubers are knobby or otherwise malformed. Cracking may be caused by very rapid growth, as when a rainy period follows a long dry spell.

Thumbnail Cracks

Handling equipment is apparently the most important factor in causing "thumbnail cracks" to appear, but after the tubers have been handled, the environmental conditions under which the tubers are stored is the factor which determines the extent and the size of development of the thumbnail cracks. Warm, dry conditions cause these cracks to enlarge rapidly. Cool, high humidity conditions tend to reduce the number and severity of thumbnail cracks.

Temperature change alone without any handling does not cause the formation of thumbnail cracks. As the amount and roughness of handling increases, the amount and severity of thumbnail cracks increases.

Control – Tubers should be handled as little and as gently as possible. They should be warmed up before they are handled and should be wet when graded. After grading, tubers should be placed in storage at a high humidity (95% or more).

Fertilizer Burn

Excessive fertilizer application or fertilizer contact with tubers in dry soil may cause surface burns or severe russeting and corrugation of the tuber surface. In addition, foliage may be severely damaged.

Control – Regulate fertilizer applications.

Lightning injury

Lightning injury in a potato field is usually a well defined circular or elliptical area containing injured or killed plants. Under some conditions a clearly defined centre is frequently lacking.

Injury to potato vines is evident within a short time following the electrical discharge. The stem is usually most severely injured at or near the soil level. Pith conditions may vary from a cross hatched or ladder-like breakdown, to complete collapse. Complete collapse results in hollow stems. In some instances, the pith may be soaked and a dark bluish-green in appearance. Longitudinal furrowing of the stem with external necrotic streaking may also be evident. Leaves frequently remain green for some time following injury to the vines.

Injured tubers may show extensive collapse of the central area with less severe damage in the outer tissue, holes through the tuber, or after a time, stem-end rot.

Low Temperature Injury

Potatoes subjected to temperatures below freezing will breakdown completely and rot. If potato tubers are injured by field frost the affected portion, usually one end only, dries up leaving a flat, dry, necrotic area. If potatoes are chilled but not frozen sufficiently to cause complete breakdown of the tissue, various forms of internal necrosis may develop.

Low temperature stored potatoes will taste sweet because some of the starch has been converted to sugar. Some cultivars will also develop a reddish-brown color (mahogany browning) or dark brown color called low temperature breakdown.

Control - Potatoes should not be harvested at temperatures below freezing. They should be stored at temperatures within the safe levels accepted by the processor/receiver involved to prevent the development of mahogany browning and excessive accumulation of sugars. Supplemental heat should be provided in both storage and transit if there is a danger of the temperature dropping below freezing.

Enlarged Lenticels

Numerous white, corky growths protrude over the tuber surface, these later turn light brown. The condition is often seen on muck-grown potatoes but may develop on high land grown tubers when very wet weather precedes harvest.

Pink Ring

A pink ring often develops in the cortex and vascular ring of the Early Ohio variety. The factors responsible for inducing this condition are not known.

Internal Sprouting

A sprout developing from a deep eye provides pressure against a second sprout developing beside it. Under this pressure, the second sprout penetrates the mother tuber tissue. Expansion of this sprout splits the mother tuber tissue allowing rapid forward growth and it may soon again emerge from the tuber. If an adjacent tuber is resting against a sprouting rosette, this tuber may be penetrated by a sprout. All sizes of tubers appear to be susceptible to internal sprouting.

In some instances, internally sprouted tubers have a tendency to form small internal tubers. This process is referred to as "tuberization" and appears to be an effort of the plant to reproduce itself under stress.

Some tubers may show no outward appearance of internal sprout damage, however, inspection beneath the rosette sprout may show some damage and deeper cutting may reveal severe internal damage.

Control – Storage temperatures should be kept on the lowest margin of safe levels accepted by the processor/receiver involved. Air circulation should be uniform throughout the storage piles throughout the storage period. Hot spots that develop in bins are more susceptible to interal sprouting. Chemicals such as maleic hydrazide and isopropyl N–(3 chlorophenyl) carbamate (CLPC) are used to reduce or inhibit sprout growth in potatoes. Maleic hydrazide is applied in the field and CLPC in storage.

Jelly-End Rot

This rot occurs most often on long, narrow or pointed tubers. The symptoms appear at the stem end of the potato or occasionally on knobs. At first the flesh is glassy, jelly-like and slightly watery. As the tuber ages, the affected tissue shrivels and dies, leaving a fluffy mass. The rot does not usually spread in storage.

The rot is caused by conditions that interfere with the deposition of starch in the growing tissues, especially at the stem end of the tuber. There is some evidence that fluctuations in moisture supply during the growing season may be responsible. The disorder is most common when a hot dry summer is followed by a cool, rainy fall.

Control – Early irrigation appears to reduce the amount of rot. If irrigation is impractical, use cultural practices that help retain soil moisture, such as adequate spacing of rows and proper hilling and cultivation. Do not store potatoes if many are affected.

Stem-End Browning

If a thin slice is cut from the stem end of a tuber, there may be reddish-brown to black streaks one-half inch deep. This disorder is readily confused with the tuber symptoms of the diseases leafroll, verticillium and fusarium wilt. Stem-end browning usually develops when potato tops are killed rapidly, either by chemicals or by frost. It is sometimes caused by overuse of fertilizers or improper fertilizer mixtures.

Control – Use chemicals that kill the tops gradually. Do not dig the crop until two weeks after top killing.

Hollow Heart

Tubers with hollow heart have a normal external appearance, but they have a cavity near the centre. The cavity usually has a brown lining. Hollow heart has been attributed to:

- Moisture stress in the tuber when the tubers are beginning to develop.
- Injury to some cells in the tuber due to re-absorption of minerals and carbohydrates or depletion of food reserves followed by tuber enlargement.

Varieties differ in their susceptibility to hollow heart. Norgold Russet is highly susceptible. Netted Gem is somewhat less susceptible. Viking never show hollow heart even under extremely adverse conditions.

Control – Plants should be properly spaced. Use balanced fertilizer mixtures that provide uniform vine growth without excessive top growth. Provide plants with adequate moisture when tubers are beginning to form and throughout the growing season.

Blackheart

One or more irregularly outlined, dark grey to purple-black areas develop in the tissue of the central area of the tuber. These may extend to the surface. The affected tissues are readily invaded by bacteria and fungi that soon cause various forms of decay. If the affected tissue dries, cavities develop and the tissue becomes tough and leathery.

This disease is caused by smothering brought about by high temperatures accompanied by poor aeration. It may develop during growth under waterlogged soil conditions, or during storage and transit.

Control – Ensure proper field drainage. Maintain proper temperatures and ventilation in storage and during transit.

HERBICIDE INJURY

Injury can result from the misapplication of herbicides recommended for potatoes, drift from neighboring spray operations, soil residue or herbicide residues within the tuber itself. Growth regulating herbicides such as 2,4-D, dicamba or picloram will result in leaf cupping, fiddle heading and enlarged stems. The degree of injury and its effect on yield will vary with the herbicide and dosage involved, as well as the time and duration of exposure. Soil sterilants, if involved, will result in chlorosis, browning and eventual death not only of potatoes but other surrounding vegetation.

Control – Follow label directions during herbicide application and in crop selections in succeeding years. Potatoes cannot be planted in soils treated with high rates of dicamba for at least one year and with picloram for two – five years or more.

MISCELLANEOUS

Alberta

Garden Fax

CAUSES AND CONTROL OF AFTER-COOKING DARKENING OF POTATOES

After-cooking darkening shows up when boiled or steamed potatoes are exposed to the air. A discoloration ranging from grey to almost black develops just under the skin at the stem end of the potato, decreasing in intensity toward the apical end. This condition looks unsightly and, although the potato is quite **wholesome**, the defect leads to a great deal of wastage and is obviously undesirable. The discoloration also shows up in frozen French fries, chips, and in canned and dehydrated potatoes. This worldwide problem is not confined to any one variety or cultural condition, although both are important.

It is generally accepted that the pigment responsible for after-cooking darkening is a complex of chlorogenic acid and iron, which is formed on cooking and oxidized on cooling to give a colored complex of ferric di-chlorogenic acid. However, the formation, of this pigment can be affected by pH and by the presence of naturally occurring chelating agents (citric and malic acids and phosphate) in the tubers. **Citric acid** is the most effective of the substances which compete with chlorogenic acid for iron in the tuber to form a colorless complex. The distribution of blackening within tubers is dependent on the ratio of chlorogenic acid to citric acid; the latter acid is always higher at the bud end of the tuber, where little blackening takes place.

Although in any given variety the absolute amount of blackening and the levels of chlorogenic acid and citric acid are dependent on soil and season, blackening varies from one variety to the next and is dependent on the amount of chlorogenic acid and citric acid that a variety contains. Those varieties high in chlorogenic acid blacken the most, while those low in chlorogenic acid blacken the least. Varieties intermediate in chlorogenic acid vary in blackening according to the environmental conditions.

The effect of variety is principally on chlorogenic acid, and the effect of soil is principally on citric acid. Good correlations have been found between the amount of potassium and citric acid in tubers. Soils low in potassium produce potatoes low in potassium and citric acid, and showing a high incidence of blackening. This situation is further aggravated in the presence of high soil nitrogen, which has an antagonistic effect on the uptake of potassium. In certain soils, the uptake of iron may be restricted by soil conditions such as high pH and high levels of calcium, and under these conditions, the lack of iron may play an important role in reducing blackening. However, under these conditions, potatoes become susceptible to scab.

Reducing after-cooking darkening

1. During the production of potatoes, a number of factors can reduce subsequent after-cooking darkening.
   - Use adequate potassium fertilizer
   - Use a balanced fertilizer in the soil. Excessive use of nitrogen fertilizer increases the after-cooking darkening tendency.
2. The variety Norland is generally the most susceptible to after-cooking darkening. In order of decreasing susceptibility other varieties are Norchip, Netted Gem, Warba, Batoche and Norgold Russet.
3. Industrial control of this problem in processed potato products may be achieved through the use of sodium acid pyrophosphate.
4. Domestic control of this problem may be achieved by adding 1–2 teaspoons of lemon juice to the water before boiling potatoes.

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Copies of this and related publications may be obtained from the Publications Office, Alberta Agriculture, 9718 – 107 Street, Edmonton, T5K 2C8 or District Extension Offices.

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POTATO GREENING AND GLYCOALKALOIDS

Introduction

Potatoes exposed to light during the growing season, as a result of improper hilling, or during post-harvest handling and marketing, develop a green pigment. Often a bitter taste or an off-flavor is associated with this pigmentation. The green color arises from the synthesis of chlorophyll, but the bitterness is due to an excess formation of naturally occurring glycoalkaloids (a glycoalkaloid is a basic nitrogen compound that has one or more sugar molecules attached to it). In potatoes ∝–solanine and ∝–chaconine are the predominant forms. Though the syntheses of both chlorophyll and glycoalkaloids in potatoes are activated by light, their processes of formation are independent of one another.

Greening

Greening in potatoes is confined mainly to the outer 3 mm of the tuber. Tendency to green, and rate and extent of greening are affected by several factors:

Variety – Marked differences occur between varieties in rate of greening during exposure to light. The white-skinned variety Kennebec greens very rapidly. Greening which occurs in russeted and red-skinned varieties may be masked and not as readily detected.

Maturity and Age – Immature potatoes have a thin skin and are likely to be highly susceptible to greening. Newly harvested potatoes green more rapidly than the same potatoes after several months storage.

Temperature – Potatoes green faster, under light exposure, at high rather than at low temperatures. Chlorophyll develops slowly in potatoes exposed to light at 5°C, and rapidly at 20° and 26°C. However, potatoes stored at 5°C for 2 weeks and then placed at room temperature in the light develop green pigments more rapidly than those stored 2 weeks at 20 – 30°C, before exposure.

Intensity, Quality and Duration of Light – Potaotes will green under low light intensity if sufficient exposure time is given. Greening will increase with increasing light intensity though not in direct proportion to the light intensity. Wavelength of light may also affect chlorophyll development. Under artificial conditions green light induces the least chlorophyll formation; red and blue induce more; and white fluorescent light induces the most.

Once present chlorophyll does not disappear readily from tubers. Greened tubers show little change in chlorophyll concentration even after 100 days storage in the dark.

Glycoalkaloids

In small amounts, glycoalkaloids are normal constituents of potato tubers. They are partly responsible for the characteristic flavor of potatoes, and may also be a factor in protecting the plants from insects and other pests. Under normal conditions the glycoalkaloids are present in potato tubers in low concentrations and are harmless to humans. However, under certain conditions, even in the absence of greening, excess formation of glycoalkaloids can occur, resulting in unacceptable levels of these toxic substances in the potatoes. These glycoalkaloids are higher in the vicinity of the eyes of the tuber, sprouts contain much more glycoalkaloids than the tubers, and the peel will contain more than twice as much glycoalkaloids as the flesh of the tuber. Peeling therefore, removes the bulk of the offending substances, unless prolonged storage has permitted these toxins to spread gradually toward the center of the tuber.

Tubers with more than 20 milligrams of glycoalkaloids per 100 grams of fresh weight are considered unsuitable for food purposes.

There are many instances where potato tubers will show high levels of glycoalkaloids and no greening. In like manner, greening of tubers does not necessarily indicate a high glycoalkaloid content.

In some cases high glycoalkaloid levels have been found to be caused by the enivronment after harvest. Netted Gem potatoes, for example, can triple their glycoalkaloid content after 6 to 8 hours of exposure to sunlight under conditions of near freezing temperatures. Other factors that may contribute to high glycoalkaloid levels are: illumination of tubers during early storage, high temperatures in excess of 10°C during harvest, and storage and mechanical injury. An increase of up to 120 mg glycoalklaoids per 100 gm of tuber may occur near a wound as a result of bruising, cutting, or skinning potatoes during handling. Some varieites of potatoes apparently can develop high levels of glycoalkaloids more easily than others; for example, Kennebec will attain much higher levels of glycoalkaloids than Irish Cobbler on continued exposure to light. Also, immature tubers develop high levels of glycoalkaloids easier than mature tubers.

An important point to note is that glycoalkaloids are not destroyed by cooking, therefore, the only effective way to avoid their intake is to prevent them from increasing in the tubers.

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The Following are Recommended Procedures to Control Greening and Glycoalkaloids in Tubers:

- Keep tubers well covered with soil during the growing period.
- Allow the tubers to mature before harvesting.
- If possible, avoid harvesting potatoes on a clear, sunny day when the temperature is near freezing, or may drop to near freezing.
- Do not leave potatoes to dry in the field.
- Avoid handling methods that cause bruising or skinning of tubers.
- Expose tubers to the least possible amount of light during grading and other operations.
- Store tubers under proper conditions in super markets and in the house. If tubers are displayed in transparent plastic bags, the length of time they are under light should be kept to a minimum. Shield potatoes from direct light or store tubers in total darkness whenever possible.
- Control insects,particularly the Colorado potato beetle. Injury to potato vines or insect damage are known to increase the glycoalkaloid content of the tubers.

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1. Diseases and Pests of Potatoes. Publication 1492, Agriculture Canada, Ottawa. 1974.

2. Potato Diseases. Agriculture Handbook No. 747. United States Department of Agriculture, Washington. 1976.

3. Market Diseases of Potatoes. Agriculture Handbook No. 479. United States Department of Agriculture, Washington. 1978.

4. Guidelines for the Control of Plant Diseases in Western Canada. Western Committee on Plant Disease Control. 1983.

5. Compendium of Potato Diseases. American Phytopathological Society, St. Paul, Minnesota. 1981.

Simple Conversion Table of Length

Inches	1	2	3	4	5	6	7	8	9	10	11	12	
Centimetres	2.54	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40	27.94	30.48	(approx 0.3 m)
Feet	1	2	3	4	5	6	7	8	9	10			
Metres	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0			
Miles	1	2	3	4	5	6	7	8	9	10			
Kilometres	1.6	3.2	4.8	6.4	8.0	9.7	11.3	12.9	14.5	16.1			

Simple Conversion Table of Weight

Ounces (av)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Grams	28.3	56.7	85.0	113.4	141.7	170.1	198.4	226.8	255.1	283.5	311.8	340.2	368.5	396.9	425.2	453.6*
Pounds	1	2	3	4	5	6	7	8	9	10						
Kilograms	0.45	0.91	1.36	1.81	2.27	2.72	3.18	3.63	4.08	4.54						

*(approx 0.45 kg)

Simple Conversion Table of Temperature

Degrees Fahrenheit	0	10	20	30	32*	40	50	60	70	80	90	100	200	212	400
Degrees Celsius	−17.8	−12.2	−6.7	−1.1	0*	4.4	10.0	15.6	21.1†	26.7	32.2	37.8	93.3	100.0	204.4‡

*(Water Freezes)
†(Room Temperature)
‡(Hot Oven)

Simple Conversion Table of Area

Square Inches	1	2	3	4	5	6	7	8	9	10
Square Centimetres	6.45	12.90	19.36	25.81	32.26	38.71	45.16	51.61	58.06	64.52
Square Feet	1	2	3	4	5	6	7	8	9	10
Square Metres	0.09	0.19	0.28	0.37	0.46	0.56	0.65	0.74	0.84	0.93
Acres	1	2	3	4	5	6	7	8	9	10
Square Metres	4 047	8 094	12 141	16 187	20 234	24 281	28 328	32 375	36 422	40 469

Simple Conversion Table of Volume

Ounces (fl.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Millilitres	28.4	56.8	85.2	113.7	142.1	170.5	198.9	227.3	255.7	284.1	312.5	341.0	369.4	397.8	426.2	454.6
Ounces (fl.)	17	18	19	20												
Millilitres	483.0	511.4	539.8	568.3 (approx. 0.57 £)												
Pints	1	2	3	4	5	6	7	8	9	10						
Litres	0.57	1.14	1.70	2.27	2.84	3.41	3.98	4.55	5.11	5.68						
Gallons	1	2	3	4	5	6	7	8	9	10						
Litres	4.5	9.1	13.6	18.2	22.7	27.3	31.8	36.4	40.9	45.5						

Canada metric Canada métrique

METRIC CONVERSION TABLE

Approximate conversions to metric measures

When You Know	Multiply by	To Find	Symbol
LENGTH			
inches	2.5	centimetres	cm
feet	0.3	metres	m
yards	0.9	metres	m
miles	1.6	kilometres	km
AREA			
square inches	6.5	square centimetres	cm^2
square feet	0.09	square metres	m^2
square yards	0.8	square metres	m^2
square miles	2.6	square kilometres	km^2
acres	0.4	hectares	ha
MASS			
ounces	28	grams	g
pounds	0.45	kilograms	kg
short tons (2000 lb)	0.9	tonnes	t
VOLUME			
fluid ounces	28	millilitres	ml
pints	0.57	litres	l
quarts	1.14	litres	l
gallons	4.5	litres	l
cubic feet	0.03	cubic metres	m^3
cubic yards	0.76	cubic metres	m^3
TEMPERATURE (exact)			
Fahrenheit		Celsius	°C

°F - 32 x 5/9 = °C

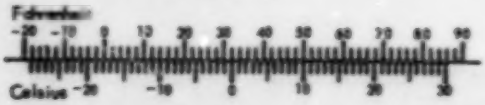
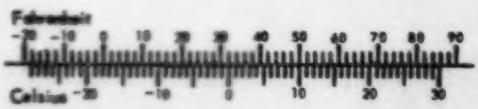


TABLE DE CONVERSION MÉTRIQUE

Conversion approximative aux unités métriques de mesure

Lorsque vous connaissez les mesures en	Multipliez par	Pour obtenir	Symbole
LONGUEUR			
pouces	2.5	centimètres	cm
pieds	0.3	mètres	m
verges	0.9	mètres	m
milles	1.6	kilomètres	km
SUPERFICIE			
pouces carrés	6.5	centimètres carrés	cm^2
pieds carrés	0.09	mètres carrés	m^2
verges carrées	0.8	mètres carrés	m^2
milles carrés	2.6	kilomètres carrés	km^2
acres	0.4	hectares	ha
MASSE			
onces	28	grammes	g
livres	0.45	kilogrammes	kg
tonnes courtes (2000 lb)	0.9	tonnes	t
VOLUME			
onces liquides	28	millilitres	ml
chopines	0.57	litres	l
pintes	1.14	litres	l
gallons	4.5	litres	l
pieds cubes	0.03	mètres cubes	m^3
verges cubes	0.76	mètres cubes	m^3
TEMPÉRATURE (exacte)			
Fahrenheit		Celsius	°C

°F - 32 x 5/9 = °C



Metric Commission

Commission du système métrique

POOR

QUALITY

ORIGINAL